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Contrasting Approaches: The Ozone Layer, Climate Change, and Resolving the Kyoto Dilemma

by

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CONTENTS

I. INTRODUCTION: APPLES AND ORANGES? 3

II. MONTREAL: AN UNLIKELY SUCCESS STORY 4

III. LESSONS FROM THE OZONE LAYER 7

IV. CLIMATE CHANGE: THE ROAD TO RIO 11

V. THE FRAMEWORK CONVENTION ON CLIMATE CHANGE 14

VI. TORTUOUS TARGETS IN KYOTO 16

VII. WHEN WILL THE KYOTO PROTOCOL ENTER INTO FORCE? 19

VIII. UNLEARNED LESSONS 22

IX. TIME TO MOVE ON: A LONGER TERM PERSPECTIVE 26

X. A TECHNOLOGY-BASED STRATEGY FOR THE FUTURE:
EIGHT POINTS FOR ACTION 29

BIBLIOGRAPHY 34

I. INTRODUCTION: APPLES AND ORANGES?

In December 1997, after days and nights of bargaining that culminated two years of hard negotiations, representatives of 160 governments wearily agreed in Kyoto, Japan, on a protocol to supplement the 1992 United Nations Framework Convention on Climate Change. It was hoped that this "Kyoto Protocol" would represent a major step forward by the international community to mitigate emissions of greenhouse gases that could alter future climate. Before long, however, doubts emerged on whether the treaty was implementable, and even whether enough governments would ratify to allow its entry into force as international law. Nearly two years later (November 1999), a mere 16 nations – mostly small island states -- had ratified. None were significant emitters of greenhouse gases.

Just a decade earlier, only 24 countries had signed the Montreal Protocol on Substances That Deplete the Ozone Layer. This treaty, however, entered into force within 15 months, has been ratified by 168 nations, and has entered into the annals of diplomacy as a landmark in the history of international cooperation. The heads of the World Meteorological Organization (WMO) and the United Nations Environment Programme (UNEP) described the 1987 Montreal Protocol as "one of the great international achievements of the century." (Bojkov 1995)

Much has been written about the pathbreaking nature of the ozone accord. Its unexpected success was viewed as an encouraging sign that the world would now be able to cooperate in addressing such other long-term environmental threats as climate change and diminishing biological diversity. The Montreal Protocol was mined for pertinent lessons for the future.
(Lang 1996, French 1997, Benedick 1998a)

However, negotiations over climate change, from their very inception in Chantilly, Virginia, in February 1991, have been marked by persistent disarray among the negotiating parties on the necessity and feasibility of strong early

measures to remodel the world's energy structure. Proponents of decisive action became increasingly frustrated by the continuing hesitancy on the diplomatic front – a lack of zeal that was manifested, ironically, by many of the same nations that have been traditional leaders on ozone, air and water quality, wildlife and other environmental issues, notably Australia, Canada, New Zealand, and the United States.

Environmental advocates attributed the negotiating problems not to flaws in the international approach to climate, but rather to short-sighted politics, selfish pecuniary interests, and unenlightened lifestyles of a few rich countries. The arguments on all sides became increasingly shrill, the rhetoric more inflammatory. Irritation over the climate stalemate led some revisionists to label the Montreal Protocol as an easy victory that has no relevance for the more complex subject of climate change. Ozone layer and climate change? It seemed like comparing apples and oranges.

The scientific and socioeconomic variables associated with global climate are indeed more complicated than those that faced the negotiators of the Montreal Protocol. However, this alone is not a satisfactory explanation for the continuing disputes over restricting anthropogenic greenhouse gas emissions. Far from being disqualified, the ozone experience offers lessons that are fundamental to understanding why the climate negotiations so far have been so unproductive.

II. MONTREAL: AN UNLIKELY SUCCESS STORY

As an historian once observed, all revolutions seem impossible before they occur -- and inevitable afterwards. Now that chlorofluorocarbons (CFCs) has become a household word, we forget the global firestorm of controversy that was provoked by a technical article written in 1974 by two scientists at the Universe of California at Irvine. Sherwood Rowland and Mario Molina hypothesized that certain anthropogenic chemicals could damage ozone molecules 30 to 50 kilometers above the Earth's surface. (Molina and Rowland 1974) If true, the theory had portentous implications, since the evolution of life was possible only because this fragile layer of stratospheric ozone absorbs

dangerous ultraviolet radiation (UVB) from the sun. Twenty-one years later, Rowland and Molina would receive a Nobel Prize for their discovery, but at the time, their theory was attacked and derided. The earliest chronicle of the ozone history bore the apt title, *The Ozone War* (Dotto and Schiff 1978).

When a handful of governments convened in Stockholm in 1982 to begin negotiating an international agreement on the problem, no gambler would have wagered that their deliberations would lead just eight years later to the banning of all CFCs and related chemicals. Indeed, the first result of their arduous negotiations, the 1985 Vienna Convention for the Protection of the Ozone Layer, did not even mention CFCs – it was essentially merely a plea for more research.

Was the Montreal Protocol inevitable? We may have forgotten that CFCs, which had been invented in the 1930's, were for decades considered ideal chemicals. Nontoxic, nonflammable, noncorrosive, cheap and easy to produce, CFCs and their bromine cousins, the halons, were by the 1970's finding an ever-widening range of uses in thousands of products and processes across dozens of industries. Food processing, plastics, solvents, cleaners, air-conditioning, fire fighting, defense, aerospace, oil rigs, computers, pharmaceuticals, telecommunications, home products, industrial chillers, insulation, are only a sampling of the extent of their utility. Their benefits were virtually synonymous with modern standards of living and, except for aerosol sprays, no feasible alternatives to them existed. Industry warned that restricting their use would jeopardize nearly $400 billion in capital investment and hundreds of thousands of jobs worldwide. (Benedick 1998a:134)

We may also have forgotten that large producing nations, together accounting for two-thirds of global production -- the European Union, Japan, and the then-Soviet Union -- adamantly opposed strong limits on CFCs. The United States was the only major producer to endorse meaningful controls; it was joined by a few small consumers/producers: Australia, Canada, Finland, New Zealand, Norway, Sweden, and Switzerland. Most of the rest of the world was indifferent, epitomized in the remark to me by an Indian diplomat: "rich man's problem -- rich man's solution."

Most significant of all, we may have forgotten that during the entire negotiating period from 1982 to the protocol signing in 1987, there was absolutely no scientific evidence either of ozone depletion caused by CFCs, or of any of the predicted negative consequences – higher levels of UVB radiation at Earth's surface, increased incidence of skin cancer and cataracts, defects in the human immune system, damage to crops and marine life. The case for international controls was based entirely on arcane theories of complex chemical-physical interactions and computer model predictions of remote trace gases that were measured in concentrations as minute as parts per trillion.

Ironically, the scientists advised us not to consider the only evidence of actual ozone depletion at hand – a dramatic but temporary seasonal thinning of the ozone layer over Antarctica that was unexpectedly revealed by British balloon-based measurements in 1983, after having been overlooked in more sophisticated satellite data. The processes at work here were poorly understood, and there were at the time plausible explanations for the Antarctic event other than CFCs. Interestingly, scientists had more confidence in their theoretical models that predicted a gradual thinning of ozone over the mid-latitudes rather than a precipitous but transitory collapse over the South Pole. The "ozone hole" had even diminished in 1986 – just before protocol negotiations began; scientists did not yet know of the quasi-biennial oscillation, and thus could not be sure whether these data signaled a reversal of the depletion trend. Scientists warned me then that if we based our case on the Antarctic phenomenon and it turned out that CFCs were not to blame, the chances for reaching an agreement on strong controls would be severely undermined. (Benedick 1998a:19-20)

Only a few weeks before the final negotiating round in Montreal, many knowledgeable observers did not believe an agreement would emerge. In the face of these not trivial obstacles, what made the Montreal Protocol memorable?

III. LESSONS FROM THE OZONE LAYER

Out of the many important aspects of the ozone history, I would like to highlight five factors that appear most relevant to the climate negotiations: (1) the role of science and scientists; (2) the necessity for strong and consistent leadership; (3) the flexible design of the Montreal Protocol; (4) the technological revolution that emerged from public-private sector partnership; and (5) the involvement of developing countries in the solution.

1. Science played a crucial role not only in uncovering the threat to the ozone layer, but also in the diplomatic efforts to address the danger. Without the constant involvement of scientists, the Montreal Protocol could never have become a reality. Spearheaded by American scientific agencies -- the National Aeronautics and Space Administration (NASA) and the National Oceanic and Atmospheric Administration (NOAA) -- a remarkable cooperative international venture was launched in 1984 involving over 150 scientists from many nations. The result, published by WMO and UNEP in 1986, was the most comprehensive analysis of stratospheric chemistry and physics ever undertaken: three volumes containing over 1,100 pages of text, plus 86 reference pages listing hundreds of peer-reviewed articles. (WMO/UNEP 1986). Scientists also collaborated to develop ever more refined instruments to measure the gases, as well as sophisticated computer models to predict the implications of physical/chemical processes.

   An international scientific consensus was not by itself, however, a sufficient precondition for policy action. Scientists had to leave their laboratories and assume, alongside the diplomats, an unfamiliar share of responsibility for the policy implications of their findings. For their part, political and economic decision makers needed to fund relevant research and to work together with scientists on realistic assessments of the risks.

2. While the consequences of ozone layer depletion could be devastating, they were unproved during the negotiations. Nevertheless, it was essential to impose preventive controls well before significant impacts were recorded, because the long atmospheric lifetimes of CFCs meant that it would take decades for the ozone layer to recover. Since most governments at the start

were unwilling to undertake meaningful actions, strong and decisive leadership was needed to push the negotiations forward.

This leadership was provided by the United States, and by UNEP under its Egyptian Executive Director, Mostafa Tolba. Tolba employed his credentials as a scientist and his personal credibility with developing nations on behalf of a strong treaty. His logic and compassion made Tolba an eloquent spokesman for the interests of future generations.

For its part, the U.S. State Department designed a diplomatic campaign to counteract the influence over the European Union (EU) of such powerful companies as Imperial Chemical Industries and France's Atochem, while cultivating discreet support behind the EU communal curtain from Belgium, Denmark, and Germany. At the same time, we sent diplomatic and scientific teams to try and persuade the other two major producers -- Japan and the Soviet Union -- as well as developing nations, to support strong controls.

There were fascinating aspects of this diplomatic strategy. We initiated, for example, an unusual Cold War space-agency research cooperation -- an "ozone glasnost." We also dispatched representatives of American environmental groups to motivate their British counterparts to raise embarrassing questions in Parliament, an inspiration that elicited a formal protest from Her Majesty's Government over my involvement. In the end, Japan and the Soviet Union unexpectedly joined the U.S. and its allies at Montreal. The EU, now isolated and under pressure from its internal dissenters, was forced to compromise, and the protocol became reality. The United Kingdom (U.K.) later became a vigorous advocate of CFC phaseout. (Benedick 1998a: chapter 6)

3. Scientific uncertainties decisively influenced the protocol's design. U.S. negotiators realized that a total ban on ozone depleting substances was neither justified by existing scientific knowledge nor politically feasible. Therefore, in place of the immutable commitments of traditional treaties, the protocol was deliberately drafted to constitute a dynamic and flexible process. The "spirit of Montreal," which became a hallmark of later negotiations to strengthen the protocol, was to proceed incrementally in

small, cumulative steps, rather than to reach for over-ambitious targets that would only serve to harden opposition.

The key element was the establishment of independent expert panels to provide periodic reassessments of scientific, technological, and economic developments. These panels eventually involved hundreds of specialists from the research community and the private sector worldwide, constituting an unparalleled body of expertise available to the parties to the protocol.

When serious differences arose during negotiations, the parties regularly returned to the panels with requests for new technical analyses of policy options. Linking the protocol consistently with the science proved an effective method to minimize confrontation and, step-by-step, to gradually overcome opposition to stronger measures. The result was that the political consensus held together as the number of controlled chemicals grew from an original 8 to more than 90, while phaseout periods were gradually introduced and then systematically tightened. Based on the expert findings, the protocol was significantly strengthened through amendments at the Meetings of Parties in London in 1990, Copenhagen in 1992, Vienna in 1995, and Montreal in 1997. (Benedick 1998a:218-224, 319-320)

4. The Montreal Protocol was technology forcing in the sense that, at the time of its signing in 1987, replacements were unavailable for nearly all uses of ozone depleting substances. The cooperation of industry was fostered by a combination of factors: targets that were challenging without being impossible, the engagement of governments and international agencies, and the gradually compelling nature of the science. As a result, the initially monolithic industry opposition was undermined and more progressive elements were stimulated to look for solutions.

   By unleashing the creative energies of the private sector, a technological revolution was achieved even where alternatives had been considered impossible. Governments, international agencies, research institutes and environmental organizations often collaborated with private firms in the search for substitutes. Rival chemical producers were encouraged to cooperate in toxicity testing and other studies on possible replacements. User companies in the telecommunications sector, such as Northern

Telcom and AT&T, did not wait for the chemical industry, but reexamined their own manufacturing processes and came up with approaches, e.g., to cleaning microchips, that were even cheaper and more effective than the once-indispensable CFCs. Governments adopted market-oriented policies and incentives, and the resultant competitive forces helped to lower costs and to bring new alternatives quickly to market. Successful innovation in some fields gave the parties confidence to accept stronger controls in others. (Cook 1996, Benedick 1998a:197-202)

5. In order to address the global problem effectively, it was essential that all nations – North and South – abjure use of ozone depleting substances. Otherwise, efforts of the richer countries would eventually be swamped by developing countries with their rapidly rising populations and aspirations for economic growth. Here, again, the Montreal Protocol offers relevant lessons.

   The industrialized countries from the start accepted the principle that they would take earlier and stronger measures than the poorer nations. Attempts by some populous developing countries to promote upper-use limits on a per capita basis were firmly rejected. Instead, a ten-year grace period was agreed before developing nations had to accept obligations. Surprisingly, even this provision turned out to be mainly symbolic in importance. Developing nations moved faster than expected to replace CFCs, as the North followed through on commitments to ensure that new technologies would expeditiously be made available, and that incremental costs would be compensated through a special multilateral fund.

   Varied creative initiatives promoted the transfer of technology. Consortia of private companies, environmental organizations, and international agencies diffused new products and processes to developing countries. Greenpeace invested in an East German company to develop CFC-free refrigerators that were later distributed in China and India through the German and Swiss official aid programs. A UNEP information clearing house and training workshops reinforced efforts to spread technological innovations.

   As technology transfer became a reality rather than just words in a treaty, the developing countries became eager to obtain new technologies as

rapidly as possible. One result was the frustration of India's hopes to become the monopoly supplier of CFCs in growing Third World markets. India had utilized the grace period to expand CFC capacity in a calculated attempt to replace the North as its production phased out. But India found itself with overcapacity as its neighbors closed their doors to the outdated products. The availability of modern technologies stimulated the South to assume stronger commitments, and most developing countries will now achieve phaseout of most substances well ahead of their agreed schedules. (Benedick 1998a: chapter 16)

IV. CLIMATE CHANGE: THE ROAD TO RIO

Worries about global warming are not new. More than 40 years ago two scientists at the Scripps Institution of Oceanography, Roger Revelle and Hans Suess, warned that the accumulation of carbon dioxide in the atmosphere resulting from fossil fuel combustion represents "a large scale geophysical experiment" on the planet. (Revelle and Suess 1957) As data in subsequent years confirmed a rapid increase in atmospheric concentrations of carbon dioxide and other long-lived greenhouse gases, scientific concern mounted over possible future adverse effects, especially since disruptions in the forces that influence climate would not be easily reversible.

In 1985, WMO and UNEP, in cooperation with the International Council of Scientific Unions, convened a scientific conference in Villach, Austria, that attracted political notice when it concluded:

> "Many important economic and social decisions are being made today on long-term projects ... based on the assumption that past climatic data ... are a reliable guide to the future. This is no longer a good assumption since the increasing concentrations of greenhouse gases are expected to cause a significant warming of the global climate in the next century." (Bolin et.al. 1986)

Even greater political attention focused on climate at the 1988 Toronto Conference on the Changing Atmosphere: Implications for Global Security.

This conference, convened by the Canadian government together with WMO and UNEP, brought together representatives of government, industry, environmental organizations, and research institutes. For the first time at this level, recommendations called for negotiation of a global convention containing specific targets and timetables to reduce emissions of greenhouse gases. Other international conferences followed, and climate change and the ozone layer were even discussed at annual summits of the Group of Seven, the leaders of the major Western industrialized nations.

Coincidentally, the public was becoming increasingly sensitized to anthropogenic disturbance of atmospheric systems by the confirmation in 1988 that CFCs were indeed responsible for the Antarctic ozone hole, and by concerns in Europe and North America over acid rain and forest damage. In the same year, extreme storms over Europe, record heat waves and drought in North America, and weather anomalies elsewhere in the world heightened public attention to the possibility of changing climate. Mass media sensationalized the issue with cover stories portraying famous landmarks (e.g., New York's Empire State Building) partially submerged by raging tides.

The year 1988 was also significant for the establishment of the Intergovernmental Panel on Climate Change (IPCC), an event that was not without controversy. Previously, an eminent but largely self-selected scientific advisory group had issued pronouncements on climate at Villach and elsewhere under WMO and UNEP auspices. The IPCC idea, modeled after the successful experience of the 1984-85 ozone assessment mentioned above, was first raised in 1987 by myself and others with the aim of expanding the small group into a larger entity under governmental auspices.

Some environmental advocates opposed the concept, fearing that governments would co-opt the scientific process and distort the findings for political purposes. I and other supporters of change, however, argued that expansion of the informal group into an official panel would enhance its credibility and influence – and that, moreover, scientists would not allow themselves to be manipulated. As it turned out, the IPCC did operate with an independence that occasionally made governments uncomfortable. Drawing on the ozone experience, the IPCC became an ongoing series of roundtables, workshops, and reports, eventually involving over two thousand scientists and

researchers from many nations, organizations, and industries in data gathering, analysis, and debate. (IPCC 1991, 1996)

Based on initial IPCC findings, the UN General Assembly in December 1990 created the Intergovernmental Negotiating Committee on Climate Change, aiming at a convention for signature at the 1992 UN Conference on Environment and Development in Rio de Janeiro. The negotiations proved very difficult, since greenhouse gas emissions were inextricably linked with energy, industry, land use, and transportation policies – the building blocks of modern economies, both North and South. The interrelated aspects of the problem meant that there were no quick or obvious solutions. Mitigation policies would entail major changes in the ways that people lived, worked, and consumed.

Nations would have to significantly reduce their dependence on fossil fuels, which accounted for more than half of greenhouse gas emissions. Agricultural practices that caused emissions of nitrous oxide and methane would need to be modified. The widespread destruction of forests and savannas would have to be curtailed, as these practices not only released carbon dioxide but also removed a critical sink for absorbing emissions from other sources. Since all these factors were related to the needs of poor people in developing countries, issues of poverty and population growth were also central to mitigating climate change.

Widely varying national interests had to be reconciled in the climate negotiations. Regions and countries differ considerably in their vulnerability and in their capacity to adapt to climate change. Prospects are least favorable for the poorest countries, especially low-lying small island states, delta regions, and arid areas of Africa, South America, and Central and South Asia. Countries also differ in their industrial and transportation structure, in their natural resource base, and in their dependence on fossil fuels. China, with almost 1.3 billion people striving for higher standards of living, is unlikely to forego use of cheap coal, of which it possesses approximately one third of known global reserves, in the absence of feasible alternatives. Other rapidly industrializing countries such as India, Mexico, South Korea and Thailand share similar views on energy use. Norway and Australia are major coal exporters. Countries with large forested areas, such as Brazil, Indonesia, Malaysia and Zaire, resist attempts by the North to dictate how they may use their national patrimony.

United States prosperity is heavily dependent on domestic coal and imported oil. The economies of Kuwait, Saudi Arabia, Venezuela and others rest on oil exports. Even New Zealand, with more sheep than people, is cautious about imposing controls on methane emissions. (Benedick 1997a)

V. The Framework Convention on Climate Change

Notwithstanding the difficulties, the UN Framework Convention on Climate Change (FCCC) was signed on schedule in June 1992 by over 150 nations. (United Nations 1992) The convention was criticized by environmental groups for not mandating reductions in greenhouse gas emissions comparable to the Montreal Protocol commitments on CFCs. Instead, article 4 somewhat ambiguously obliges industrialized countries to "adopt national policies and take corresponding measures" with the "aim of returning" anthropogenic emissions by 2000 to their levels in 1990. (The 38 industrialized nations are listed in Annex I of the convention and are thus customarily termed "Annex I" countries.) At the present writing in the year before this deadline, it is evident that only a handful of Annex I countries can achieve this "aim," and those few only because of exceptional circumstances – a fact that demonstrates how ambitious the target actually was.

The framework convention is, in fact, much stronger than its true ozone analogue, which was not the Montreal Protocol but the earlier 1985 Vienna Convention. The FCCC mandates rigorous national reporting by industrialized countries on the results of the above-mentioned measures. Significantly, it also requires the parties to periodically assess the "adequacy" of the commitments, with the clear implication that revisions were intended. Further, the FCCC recognizes the precautionary principle as a criterion for such action: "Where there are threats of serious or irreversible damage, lack of full scientific certainty should not be used as a reason for postponing such [precautionary] measures" (article 3). The FCCC also contains commitments for *all* parties – North and South -- to develop national programs "to mitigate climate change by addressing anthropogenic emissions by sources and removal by sinks;" no deadlines, however, were set for establishing such programs.

Like the Montreal Protocol, the FCCC was clearly conceived to establish a long-term and dynamic process of addressing climate change. In this context, I believe that the convention's strongest feature is its "ultimate objective" (article 2), against which all future commitments must be measured:

> "The ultimate objective [is to achieve] stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system. Such a level should be achieved within a time-frame sufficient to allow ecosystems to adapt naturally to climate change, to ensure that food production is not threatened and to enable economic development to proceed in a sustainable manner."

It is unfortunate that the state of the science, then as now, cannot yet inform us what level of concentrations would be "dangerous," nor what the desirable time frame might be. Even though the lack of such indices complicates the task for governments to negotiate meaningful quantitative commitments, the concepts incorporated in the objective are valid guides for action.

At the convention's First Conference of Parties, in Berlin in early 1995, the parties had available preliminary findings from the IPCC's second report. The IPCC, while somewhat lowering its previous model projections of global warming and sea-level rise, nevertheless expressed greater confidence in the revised estimates. Most significantly, the panel for the first time concluded that the data indicated the presence of "a discernible human influence on global climate." (IPCC 1996)

Influenced by the IPCC findings, the parties in Berlin formally acknowledged that the article 4 commitments made in 1992 by industrialized countries were not adequate. They could not, however, agree on how these commitments should be strengthened. After heated negotiations, the result was a compromise: a "Berlin Mandate" required the parties to negotiate, by 1997, "quantified limitation and reduction objectives within specified time-frames" – otherwise known as targets and timetables – "for anthropogenic emissions by sources and removals by sinks."

VI. TORTUOUS TARGETS IN KYOTO

Even industrialized countries differ widely among themselves in geography, population, natural resource base, climatic conditions, industrial structure, and dependence on energy. Since these critical parameters are either intrinsic or immutable in the short run, it is extremely difficult to establish short-term emissions targets that are both economically feasible and equitable. Nevertheless, the Kyoto negotiators tried.

The centerpiece of the Kyoto Protocol is the commitment by Annex I countries, *as a group*, to reduce their net emissions of a weighted basket of six greenhouse gases by 5.2 percent below 1990 levels when averaged over the five-year period 2008-2012. (United Nations 1997) The gases are carbon dioxide, methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons, and sulfur hexafluoride; parties have the option of measuring the latter three gases against either a 1990 or a 1995 baseline. Within the Annex I group, individual states committed themselves to differing reduction targets, e.g., 8 percent for Switzerland, the European Union, and many Central and East European nations; 7 percent for the United States; 6 percent for Canada, Hungary, Japan and Poland; 5 percent for Croatia. New Zealand, Russia and Ukraine were not required by Kyoto to lower emissions below 1990 levels, while negotiators from Australia, Iceland and Norway were successful in obtaining acquiescence to higher emissions (article 3).

The 15-nation European Union committed to 8 percent as a bloc. However, it was understood that inside the EU "bubble" 11 member states could not attain this target. Rather, the EU depends on much steeper reductions by Germany and the United Kingdom to lower the community average. In both these cases, special circumstances prevailed that were independent of climate change mitigation policies. Reunified Germany benefited from the 1990 base year that incorporated high emissions in the former German Democratic Republic before they plummeted due to economic collapse. In the United Kingdom, the Thatcher Government's campaign to weaken the power of coal unions stimulated switching to natural gas – which is much less carbon intensive.

As governments appeared unwilling to confront powerful industrial interests head-on by enacting sector-specific policy measures to limit use of fossil fuels, e.g., in transportation or utilities, they opted instead for arbitrary short-term overall targets. The result was that the numbers so feverishly bargained in the midnight hours at Kyoto bore no relationship to either scientific or economic realities. The Kyoto Protocol thus inadvertently manages to be simultaneously far too strong in the short run, and yet far too weak to address the long-term problem of climate change.

The 11-15 year Kyoto targets are clearly inadequate to make any dent in future atmospheric concentrations, which is the crucial measure of danger to climate. Even if the protocol were fully implemented, it would only serve to delay by less than a decade the date in the next century at which global carbon dioxide concentrations would cross the 550 parts per million (ppm) mark that represents a doubling of pre-industrial concentrations. (Edmonds 1999b) In fairness, Kyoto was intended only as a first step, but its provisions provide no coherent concept for the future.

Yet how could the protocol also be too strong, when it prescribes no change at all in total emissions of industrialized countries? As a group, their emissions in 1997 already stood at the 2008-2012 target level of about 5 percent below 1990. Thanks to economic downturn and restructuring following the collapse of communism, the Eastern European countries together were in 1997 almost 30 percent below their 1990 baseline. (Bolin 1998) When one adds in the German and British declines already mentioned, total Annex I emissions were already below 1990 for reasons unrelated to climate mitigation policies.

However, other large emitters, notably the U.S. and Japan, were already well above 1990 levels and still climbing. U.S. emissions in particular have been buoyed since 1990 by considerably more vibrant economic activity compared to that of Europe. The Kyoto commitments could thus translate into emissions reductions approaching 25 to 30 percent from where they are headed in the 2008-2012 period -- the beginning of which is now little more than 8 years away. (White 1998, Benedick 1998b)

Difficulties for the U.S. and Canada are compounded by population growth rates much higher than that of Europe. This means that compliance on a per

capita basis becomes relatively more onerous -- they are, in effect, being penalized for having more liberal immigration policies. For the U.S. to meet its Kyoto commitment, carbon dioxide emissions on a per capita basis would have to drop to levels not seen since the end of World War II. In contrast, 1995 per capita emissions in the European Union were only slightly above its Kyoto target. (Meyerson 1998) The population inequity factor becomes even more significant in future years: according to the latest United Nations projections (medium, or "most likely" variant), the U.S. population by 2050 will be 37 percent higher than in 1990, while the populations of Japan and Germany will decrease by 15 percent and 8 percent, respectively. (United Nations Population Division 1999)

In the relatively short time available, cuts of the required magnitude cannot be achieved without scrapping major capital investments in power plants, factories, transport systems, and buildings, before they are obsolete – which means high costs and economic disruption. For the U.S., achieving the Kyoto-mandated reductions would require the kind of pressure that could come only from politically unacceptable high carbon taxes. (Nordhaus and Boyer 1999; Kopp 1997) Only five years ago President Clinton failed to get even a 5 cent per gallon gasoline tax increase from a Congress then controlled by his own party.

Nor is it a foregone conclusion that the EU will be able to reach its Kyoto commitment. There are signs that Germany, whose domestic 21 percent reduction goal is vital to achieving the European Union's overall 8 percent target, may be faltering in its progress. German carbon dioxide emissions began to creep upward in 1995, affected by increases from the transportation and household sectors; partial data for 1997 showed a slight rise from the industry sector. It appears that following the initial hefty decline after the 1990 East German dividend, some additional relatively easy steps were taken to stimulate energy conservation and efficiency. But the low-cost no-regrets strategies have apparently been exhausted. (Klepper 1999) Germany's situation is particularly sensitive because of persisting high unemployment, which increases the political risks of taxes or other costly instruments. The beleaguered Social Democrat/Green coalition government, reeling from unanticipated electoral defeats in 1999, may now be reluctant or unable to implement harder measures.

In 1996, carbon dioxide emissions were also on the rise in other EU member states that had set substantial domestic reduction goals in order for the EU as an entity to meet its Kyoto target – notably, the U.K., Netherlands and Belgium. (CDIAC 1999) Unless additional strong measures are adopted, the European Commission itself estimated in May 1999 that EU emissions by 2010 would rise to 6 percent above 1990. (European Commission 1999) OPEC success in raising crude oil prices in 1999 may come to the rescue by inducing further energy conservation. But all of these developments bear close watching.

VII. When Will the Kyoto Protocol Enter into Force?

In an attempt to maximize the efficiency of investments and thereby lower the economic costs of emissions reductions, the Kyoto Protocol established three "flexibility mechanisms:"

(1) *joint implementation*, whereby an Annex I country could invest in emissions-reducing projects in another Annex I country and receive some credit against its own target, provided that such project entails "a reduction in emissions by sources, or an enhancement of removals by sinks, that is additional to any that would otherwise occur" (article 6);

(2) a "*Clean Development Mechanism*," similar to (1) but involving voluntary projects in developing countries (article 12); and

(3) *international trading of emissions rights* among the Annex I parties, whereby a government or company could purchase "unused" emissions from abroad (article 17).

The United States government appears particularly eager to make use of the mechanisms – especially emissions trading with Russia and Eastern Europe -- as a means of easing the pain of domestic reductions. The U.S. also hopes that in time even developing countries can be integrated into a global emissions trading scheme, thereby opening vast potential sources of emissions rights to the carbon-hungry American economy. But many European nations, politically committed to costly domestic emissions reduction programs, claim that their

industries will suffer if U.S. competitors can avoid the equivalent strong medicine by means of offshore compliance. Thus, there is already serious disagreement over the extent to which these mechanisms should be permitted to supplement domestic actions. Moreover, when the time comes for payments, it is questionable whether the large untied and untraceable transfers of wealth to former communist and/or developing nations will be politically palatable to electorates in the West.

The flexibility mechanisms, moreover, have only been established in principle. Operating details, including definitions, guidelines, rules and procedures, reporting, accountability and verification, have been postponed for future deliberation. Although there are precedents for domestic emissions trading (e.g., sulfur dioxide in the U.S.), nothing comparable has ever been attempted on a global scale. It will be extraordinarily difficult to negotiate a trading system for an ephemeral "commodity" among nations at widely varying stages of economic development.

It is not hard to imagine fractious North-South controversy over criteria for allocating emission rights to developing countries -- according to population size, for example, as a reward for lax family planning? What happens if a country, having received hundreds of millions of dollars by selling unused rights, subsequently elects a democratic government that repudiates the "irresponsible actions" of its predecessor and insists that expanding energy use and land-clearing is essential to meet the basic needs of a desperate populace? What kind of bureaucracy would be needed to administer the system? What potential transaction costs may be involved? What possible abuses need to be safeguarded against? Will wild price gyrations be modified, for example via a futures market? Will prices of emissions rights be too low to stimulate meaningful domestic change in energy use? Or so high that they foster evasion? The questions multiply quickly.

Another critical issue left unresolved at Kyoto is the determination of "net changes in greenhouse gas emissions from sources and removals by sinks resulting from direct human-induced land use change and forestry activities, limited to afforestation, reforestation, and deforestation since 1990, measured

as verifiable changes in stocks ...” (article 3). As a potentially powerful offset to emissions from other sectors, this clause is crucial for determining compliance with the reduction targets.

The U.S. could, for instance, substantially offset its electricity, transportation, and industrial emissions by reporting carbon absorption due to agricultural soil uptake as well as forest growth. Europeans, however, are skeptical about measurement and verification of such sinks. They also argue that they are being penalized for their more responsible forest management prior to 1990, which means that they have less deforested area to replant. Further, it will be extremely hard to distinguish between naturally induced and anthropogenic changes in carbon uptake by soils and forests. There is not even technical agreement on definitions for “afforestation, reforestation, and deforestation.” Even worse, some developing countries may be tempted to lay waste to old-growth forests in order to sell credits to Northern entrepreneurs for reforestation offsets.

Thus, the current situation is characterized both by deep controversies over fundamental issues and by the possibility that important nations may have difficulties in meeting their reduction targets. It appears, therefore, problematical whether the Kyoto Protocol can become binding international law in its present form. In order for the protocol to enter into force, it must be ratified by at least 55 nations, including Annex I countries that together accounted for at least 55 percent of total Annex I carbon dioxide emissions in 1990 (article 25). As mentioned earlier, only 16 small countries – none of them in Annex I – have ratified as yet.

The chief American negotiator at Kyoto, Stuart Eizenstadt, admitted to the U.S. Senate in 1998 that it might be “years” before the treaty would even be submitted by the Executive Branch for Senate approval, which requires a two-thirds majority vote. Eizenstadt also expressed doubt whether the protocol would enter into force without U.S. ratification. (Franz 1998) This is not surprising, since the U.S. alone accounts for over 36 percent of Annex I 1990 emissions and, in a rare display of negative unanimity, the Senate in 1997 had voted 95-0 to reject any protocol that did not contain “meaningful participation” by developing countries. Absent Congressional support, the Clinton Administration has found it impossible even to secure legislation to start

curbing the still-rising U.S. emissions before formal ratification. Powerful American industrial interests have mounted a concerted campaign against the protocol.

A protracted U.S. delay could cause other Annex I countries to pause in their own ratification process, not least because of worries about competitiveness in international trade. As doubts grow within the European Union about its own ability to meet Kyoto targets, its member countries are also not rushing to ratify. Governmental hesitation fosters a wait-and-see attitude by industry and discourages the long-term investments needed for an energy transformation. Unfortunately, the worst of treaties is one that is not credible.

VIII. UNLEARNED LESSONS

Looking back at the relevant lessons from the ozone history discussed earlier, how do the climate negotiations compare?

1. On the role of science, the IPCC has mobilized the scientific community and is doing good work. There is general consensus that the greenhouse theory is robust: if concentrations continue to accumulate indefinitely, potentially calamitous climate change will occur at some future time. But no one can yet predict when this might happen, and there is much uncertainty about possible offsetting or delaying factors, notably cloud cover.

   The primary scientific problem affecting the negotiations is the question of potential harm from gradual climate change. There is no indication of the probability, timing, location, or severity of the long list of potential negative impacts ranging from flood and drought to tropical disease and severe storms. Indeed, scientists agree that some regions would probably benefit from warming during the next century due to higher agricultural output.

   In contrast to climate, the consequences of ozone layer depletion were of startling clarity: they would be global and fatal, and the anticipated time-span was a matter of a few decades. Because of this, governments decided

to take decisive measures even in the absence of proof that CFCs were yet damaging the ozone layer.

Proponents of strong actions in the climate negotiations have acted as if the impacts were comparable. But to obtain international agreement on measures that could entail substantial near-term costs, the dangers avoided must be more compelling than what a leading scientific advocate recently conceded were merely "not implausible." (Schellnhuber 1999) Interestingly, a recent survey indicated that nearly four times as many German scientists as Americans would make extreme interpretations in order to influence public opinion on climate change; in all, 60 percent of German scientists felt this was appropriate, while two-thirds of the Americans expressed disapproval of the practice. (von Storch and Bray 1999) The negotiations demonstrate, however, that attempts to compensate for lacunae in evidence by exaggerated claims often result in damaged credibility.

2. On the question of leadership, no strong country or strong personality has made mitigating climate change a consistent high priority. To be sure, there has been no lack of rhetoric when a politician felt there might be some benefit. President Bill Clinton, for example, after nearly five years in office introduced a climate-related program in late 1997 by pronouncing the issue as "one of the United States' greatest imperatives for this and future generations." (Benedick 1997b) The tension between the short-term perspective that has characterized the climate debate, and the century-scale of the problem itself, has served to inhibit the emergence of genuine leadership. Not only will "it" not happen on the watch of today's politicians, it probably won't even happen on their grandchildren's watch. Thus, each government in the negotiations has acted in its short-term interest, not looking beyond the next election. Any future leadership role will have to be based on a new vision; one suggested approach is offered in the final section of this chapter.

3. On the nature of the treaty, Kyoto was, like the Montreal Protocol, designed to begin a process. But it suffers from its short-term approach to a long-term problem. By focusing on targets only 11-15 years into the future, the Kyoto Protocol encourages governments – and industry – to look for short-term solutions. As a result, capital could be prematurely locked into investments

that, because of their own intrinsic lifetimes, would inhibit the development, and raise the costs, of the next generation of technologies that will be needed to achieve more substantial emissions reductions later in the century.

Kyoto's approach is based on faulty premises that predated the start of climate negotiations nearly nine years ago. They originated, in fact, at the 1988 Toronto Conference referred to above. That conference, following soon after the acclaimed Montreal Protocol, took precisely the wrong lesson from the ozone experience: it recommended that governments negotiate an international treaty requiring industrialized countries to cut greenhouse gas emissions by 20 percent by the year 2005. As a participant in this conference, and accepting due co-responsibility for the error, I can aver that this target was manufactured literally out of thin air. It was argued that reductions of one percent per year seemed not unreasonable, 2005 was 17 years out (it seemed a long time, then), round it up to 20 percent - and voilà!

This goal became a potent slogan wielded by some European governments as well as by environmental organizations and other advocates. It surfaced at every international meeting. It was adopted and pursued during the formal negotiations by the Alliance of Small Island States (AOSIS), a bloc created in 1991 consisting of approximately 40 countries that feared sea-level rise. A political target thus became the standard against which all other proposals would be measured throughout the climate negotiations.

We had forgotten that the first international action to protect the ozone layer was not the establishment of reductions targets in the 1987 Montreal Protocol. Rather, it consisted of loosely coordinated decisions made approximately ten years earlier by the world's largest CFC producer, the United States, by Canada, a small producer, and by a handful of importing countries, to ban the use of CFCs in aerosol spray cans. This *policy measure* had the effect of promoting new technologies that soon reduced emissions by about thirty percent. But if anyone at that time had proposed a formal *target* of that magnitude, it is doubtful whether governments would have embraced it. The relevant lessons from the ozone experience were that policy measures can lead the way by stimulating technology, and that targets are effective only when they are realistic.

4. Unlike Montreal, the climate negotiations alienated the private sector and sidestepped the issue of new technologies. The exaggerated warnings of impending catastrophe led to an early hardening of opposition instead of enlisting progressive elements in industry to start work on solutions. Because the debate started off with the wrong premises, the climate treaties played into the hands of the coal and oil, automobile, and other powerful interests that preferred a do-nothing policy. Rather than providing market signals that could induce broad technological innovation, serious efforts to implement Kyoto targets are now more likely to provoke a backlash from industry, consumers, and taxpayers.

   It is, moreover, an incredible inconsistency that the industrialized nations undertook daunting targets in Kyoto while cutting their investments in energy research and development. The U.S., Germany, Japan, U.K., and the European Union (as a separate entity), which together accounted for more than four-fifths of the world's public sector long-term energy R&D, collectively reduced their research budgets between 1985 and 1998 by 35 percent in real terms, or almost $3 billion below 1985 levels. None of the major industrialized countries currently invests the majority of its energy R&D in renewable energies. (Dooley and Runci 1999)

5. As for global participation, commitments by the South in the Kyoto Protocol are conspicuous by their absence. Throughout the negotiations, developing nations have resisted discussing even voluntary measures to restrain their emissions.

   In the case of ozone, the industrialized world in 1987 accounted for 88 percent of CFC consumption and 98 percent of production. Therefore, their actions were determining, and the role of developing countries was secondary. (Benedick 1998a:26,148) In contrast, while carbon dioxide emissions from fossil fuels and cement production in industrialized nations have been relatively stable for over twenty years, emissions from developing countries are on a steep upward trend. Between 1985 and 1995, the South's share of global emissions jumped from 29 percent to 44 percent. China's emissions are already second only to the United States; India's have surged by nearly 50 percent since 1990 and are now higher

than Germany; South Korea has passed Italy, and Mexico's emissions are almost as large as France. (CDIAC 1999) Propelled by rapid population growth and expanding industrialization, the South's emissions will probably surpass those of the North in only two to three decades. The above figures do not even include emissions from biomass energy, destruction of forests and savannas, and land degradation, which are hard to measure but add significantly to emissions from the developing world.

With the exception of the small island states and a few others, most developing nations do not act as if they realize their own vulnerability to the effects of climate change. Their reluctance to restrict use of cheap fossil fuel is understandable, given that their top political priority is to improve standards of living. Unless low-cost alternatives are available, they are unlikely to accept commitments that will primarily benefit future generations. It is also unrealistic to expect them to act as long as industrialized countries, which became rich in the process of causing the current climate predicament, appear unable or unwilling to take credible steps themselves. Regrettably, the South's arguments only reinforce worries in the North about the impact of higher energy costs on their own international competitiveness. Because energy production and consumption involve sizable long-term investments, the South risks getting locked into a fossil fuel economy in future decades that will make it progressively harder for them to modernize.

IX. Time to Move On: A Longer Term Perspective

It is difficult to admit that so much work has produced so little. One respected analyst has characterized the Kyoto Protocol as "a pinnacle of both economic and environmental globalisation." (Grubb 1999) He regards as a hopeful "achievement" that, at the divisive 1998 conference in Buenos Aires held one year after Kyoto, governments submitted a list of no less than 142 topics for which further negotiation was considered necessary! Most recently, the parties

to the FCCC, including ministers from 60 countries, assembled in Bonn in November, 1999, for two more weeks of intensive negotiations. The best that could be achieved was an exhortation to resolve the outstanding issues by the next conference, currently scheduled for late 2000.

Can the climate negotiations be reinvigorated? As a start, an attitudinal change would be helpful. Governments and NGOs could turn down the political rhetoric and stop reacting to every variation of the thermometer. We should ignore the apocalyptic warnings that emerge after every heat wave and hurricane, as well as the scientific "revelations" that are conveniently released on the eve of every negotiating session. It would be more candid to admit that the science is likely to remain imprecise for some time, and to move on.

Even with the aid of powerful computer models, complex interrelated natural processes are inherently difficult to predict. For biogeochemical systems, analysts admit that, "even if a model result is consistent with the present and past observational data, there is no guarantee that the model will perform at an equal level when used to predict the future." This is so not only because small input errors can generate significant deviations when extrapolated over long time periods, but also because dynamic natural systems may react in unexpected ways (Oreskes *et.al.* 1994; Sarewitz and Pielke 1999).

Notwithstanding, a persuasive case can be made that the potential dangers of climate change are sufficiently serious that actions should not be postponed until impacts are evident. There is an additional risk of crossing some unforeseen threshold – a sudden and irreversible climate disruption brought on by greenhouse gas concentrations passing a certain level. This risk is intrinsically non-quantifiable; but it is not zero. The Antarctic ozone collapse demonstrated that when we perturb the atmosphere, it does not necessarily respond with convenient early warning signals.

At this point we should return to basics -- namely, the ultimate objective of the FCCC. Pending further scientific evidence, we could establish a tentative goal for carbon dioxide *concentrations* – for example, 550 parts per million, a doubling of pre-industrial levels, would be about 50 percent above current concentrations. The target could later be modified to reflect both unfolding scientific knowledge and experience with technology. But it would at least

provide a perspective for starting a sequence of actions over the coming decades. To achieve even this concentration target would require that current annual global emissions be cut at least in half by the end of the next century (Edmonds 1999b, 1999c).

One of the premier American scientific institutions, the Pacific Northwest National Laboratory operated by Battelle for the U. S. Department of Energy, has made climate change a major priority for its researchers. Much of the following discussion is based on their analyses. Physicists, chemists, biologists, economists and engineers at Battelle are engaged in a broad range of projects exploring potential energy from biochemical processes, hydrogen transformation, microtechnology, and other futuristic sources. They are also examining the potential for carbon capture and sequestration, an option that could supplement new energy sources and substantially lower costs by permitting continued use of fossil fuels without burdening the atmosphere. Other Battelle research focuses on such related fields as technology policy, energy economics, local climate impacts, and new structural materials for vehicles.

Battelle's analyses make clear that greater energy efficiency, fuel switching, and expansion of existing renewable energies (solar, wind, biomass, etc.), while necessary, will not go far enough to enable the deep emissions reductions required in the latter half of the next century. What is needed is no less than a technology revolution in the energy sector.

The long atmospheric lifetime of most greenhouse gases means that concentration levels for the next century are to a great extent already predetermined by past emissions, and are therefore not significantly affected by short-term emissions cuts. However, researchers at Battelle and its partners have demonstrated that any given concentration level depends more upon cumulative emissions than upon their timing. This is a crucial point, for it thereby becomes possible to achieve a future concentration goal by choosing among differing alternative trajectories of emissions reductions. Such flexibility can significantly lower the costs of transforming the energy sector (Wigley *et.al.* 1996, Edmonds 1999c).

Emissions in 2008-2012 are thus much less important than what happens in 2040, 2060, 2080. Recent Battelle research indicates that early offsets to emissions through soil carbon sequestration can buy additional time for future steep reductions. (Rosenberg *et.al.* 1999) In sum, the analyses show that we do have time, provided that we use it well: emissions can be allowed to drift upward for awhile -- as long as we undertake actions to ensure that later emissions are substantially lower (Edmonds *et.al*. 1997).

X. A TECHNOLOGY-BASED STRATEGY FOR THE FUTURE: EIGHT POINTS FOR ACTION

What kind of actions might these be? The dangers of long-term global warming can only be averted if we (1) bring to market a new generation of cost-effective technologies that will drastically reduce dependence on fossil fuels and/or will capture and sequester carbon, and (2) gain the cooperation of key developing countries to limit their rapidly rising emissions. Fortunately, the two conditions are interrelated: as we achieve the first, we will get the second.

As the ozone history amply demonstrated, when cost-effective technologies start becoming available, developing countries are more likely to join the bandwagon and adopt modern methods. Technology functions as the "enabler," without which the high emissions reductions required in the latter half of the coming century will not materialize. We need, therefore, a new strategic vision that explicitly addresses issues of technology research, development, and diffusion.

Not only are the time-consuming negotiations to resolve the flaws of Kyoto not bringing the parties closer to consensus, they actually prevent governments from focusing on more realistic measures. The Kyoto Protocol has become the victim of polarized debate over inconsequential short-term emissions, compounded by large uncertainties about the short-term costs of compliance. The existing treaty provides inadequate attention to the technological imperative and to securing the cooperation of developing nations. The current debates distract attention from the real challenge, which is to set the stage for

reducing emissions to less than half of 1990 levels within the next century, and holding them there indefinitely.

A combination of better technology and a realistic schedule of emission reductions would significantly lower mitigation costs, which might otherwise be prohibitive, in both North and South. Battelle models suggest that technology could make a difference of trillions of dollars in the global cost of mitigating climate change (Edmonds 1999c). Major near-term cost savings could also be realized by avoiding the "stranding" of assets: existing plants and related infrastructure investments should, generally, be allowed to complete their useful lives. Companies should be provided with some security that future energy investments will not be made obsolete by new rounds of politically inspired targets that are not based on science. Buying time would also permit scientists to make further refinements in their climate models and thereby gain more insight into the impacts of climate change, especially their scope, timing, and location. This would help both in mobilizing public support for action, and in providing better guides for policy. The entire process would become politically more acceptable.[1]

A technology strategy is only defensible, however, if it is does not become an invitation to delay. Much must be done right now to start the process. Here is a possible eight-point program of action for the negotiators.

1. ***Revise and simplify the emissions targets.*** To begin, I recommend that governments streamline the Kyoto emissions commitments to make them more credible. The near-term targets should be revised in magnitude and should focus primarily on gross carbon dioxide emissions. (Methane, which has a short atmospheric lifetime and is difficult to measure, could be temporarily left out; however, the three fluorinated greenhouse gases, which have currently relatively low emissions but potentially powerful future impact, should be restricted**.**) More realistic and verifiable initial targets for

[1] Against this background, Battelle has organized an international consortium of research institutes, private companies, and government agencies to develop a global energy technology strategy. The broad scope of this initiative includes: the potential future contribution to carbon management of different technologies; the applicability of specific technologies to the varying circumstances of different regions, in particular China and India; barriers to research collaboration; strategies to promote technology diffusion and market penetration; and augmenting soil absorption of carbon through agricultural techniques. This multi-year program could be a paradigm for the type of public-private partnerships that will be indispensable for transforming the world's future energy economy.

industrialized countries would have a better chance of being implemented. Hence, they would be taken more seriously by industry as well as by the onlooking developing world. As new technologies emerge, it will be politically easier to strengthen targets over time.

2. ***Postpone the sinks.*** The attempt to reflect net emissions targets is scientifically justifiable, but the complexities surrounding the land-use and forestry provisions of article 3 are, in my opinion, a formula for delay. Therefore, the comprehensive approach should be abandoned, at least temporarily. The net emissions concept should be re-introduced after technical experts have made it implementable, but action on reducing gross carbon emissions should not wait for this refinement.

3. ***Defer emissions trading.*** For all of the reasons enumerated earlier, I would also shelve for the time being the disputatious negotiations on creating an international emissions trading scheme.

4. ***Get on with technology transfer and joint implementation.*** Governments and industry in the industrialized countries should undertake serious efforts – as they did under the Montreal Protocol – to expeditiously transfer new energy-related technologies to the developing world, and should help build indigenous capacity to develop local energy solutions. North-South and West-East joint implementation investments make sense from the standpoints of both economic efficiency and environmental effectiveness. The Clean Development Mechanism (which is the most promising element of the existing protocol) should be activated to promote greater energy efficiency and expansion of renewable energy in the developing nations. The North should provide climate-relevant assistance as a cost-effective form of foreign aid rather than primarily to earn emissions offset credits. All of this would probably be far less costly and more productive than large wealth transfers to buy emissions “rights”.

5. ***Get serious about policy measures.*** In a test of political will, the emissions targets should be reinforced by harmonized policy measures. Stricter vehicular fuel-efficiency standards (which everyone, including the automakers, knows are feasible), and energy-related government procure-

ment policies, could provide strong impetus to innovation. Existing market distortions and subsidies that favor fossil fuels should finally be eliminated. Incentives should be adopted to promote further development and market penetration of renewable energies, in order to realize economies of scale that would make them more competitive. If it proves too difficult to negotiate legally binding policy commitments, an interim fallback might be to require transparent and rigorous reporting; experience in the IMF and OECD has shown that the need to report regularly to peers can be an incentive to change policies for the better.

6. ***Consider technology-based objectives.*** Analysts are exploring possible technology-based goals that governments could employ to stimulate future-oriented R&D. Since virtually all carbon in modern energy economies flows through power generation and fuel refining/processing, such policies could be quite specific in their focus. For example, new power generation plants constructed after a certain date could be required *either* to use renewable energy *or* to capture and dispose of carbon byproducts. Similarly, new fossil fuel refining and processing facilities after a given date would also have to be carbon neutral. (To encourage R&D before the phaseout deadline, interim targets could be scheduled for new plants, as well as credits provided for early compliance.) Additionally, fossil fuels could be employed as a feedstock for hydrogen, but any carbon releases would have to be sequestered. Net imports of carbon-based fuels could gradually be phased out in the second half of the century. Because these measures apply to sizable industrial facilities, they are conducive to transparency, reporting, and monitoring for compliance. Such actions are feasible, and would provide the market with signals for focused research without imposing unrealistic generic targets that could cripple innovation.(Edmonds and Wise 1999, Edmonds *et.al*. 1999).

7. ***Invest in a technological revolution.*** Most important of all, governments must ensure that sufficient financial resources are made available to achieve the needed technological revolution. Reaching a critical mass of R&D is basic to fostering technological breakthroughs. Governments cannot stand back and expect that the private sector, with its relatively short time horizon, will make all the required long-term R&D investments. Although credible targets and policy measures can help to stimulate industry's

creativity, the scale of the climate/energy challenge requires that the public sector take the lead role. Even a small carbon tax could raise substantial revenues for funding new technology research. For example, a tax of four dollars per ton of carbon in the U.S., representing only one cent per gallon of gasoline, could generate approximately $5.6 billion and enable current public sector energy R&D to grow more than threefold.

OECD members should commit themselves to raising their grossly inadequate level of basic and applied energy research by a significant (and annually rising) percentage of civilian research programs. And they should collaborate in R&D, especially with developing nations and with the private sector. Given the stakes, energy research arguably merits a degree of public sector commitment comparable to that devoted not long ago to aerospace and telecommunications. The leverage that such research would provide in reducing the future costs of addressing climate change makes it an eminently sound investment.

8. ***Negotiate in a more efficient forum***. In the interest of speeding the process, most if not all of these actions – especially the research initiatives, policy measures, technology transfer, and technology goals -- could be negotiated and implemented by like-minded nations, North and South, outside the FCCC context (and perhaps later presented to the larger forum.) It is imperative to closely involve the handful of developing nations whose emissions really matter. There is no moral stricture, however, that requires concerned governments to negotiate every relevant action within the unwieldy context of over 170 nations and thousands of observers. The OECD and the Asia-Pacific Economic Conference come to mind as plausible alternatives.

   Together, the above efforts would greatly increase the likelihood of making existing renewable energy more competitive, making carbon capture and sequestration more feasible, creating new energy sources, and engaging developing countries. Perhaps by making a fresh start with new concepts, we could achieve the progress that has been so elusive up until now.

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